Appendix G-12: A Summary of the 2002 Base Case and 2009 Future Base Case CMAQ Runs

A Summary of the 2002 Base Case and 2009 Future Base Case CMAQ Runs

March 15, 2007

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1. **Why is this analysis important?**
   This is a discussion of the basic attainment run for Baltimore with no adjustments to account for any issues CMAQ has in predicting ozone changes. By this conservative measure, the Edgewood monitor has the high 2009 design value of 85 ppbv. This strongly suggests that Baltimore should be firmly in attainment of the 8-hour standard in 2009.

2. **What questions are answered by this analysis?**
   Does CMAQ predict attainment of the 8-hour standard by Baltimore in 2009?

3. **What are the key take-away messages of this analysis?**
   CMAQ, even with its demonstrated underprediction of ozone in response to changes in emissions, indicates that Baltimore will attain the 8-hour ozone standard in 2009.

4. **What conclusions are reached in this analysis with respect to Maryland's attainment demonstration?**
   All of Maryland will attain the 8-hour ozone standard by 2009.

Abstract

The outputs from the Community Multiscale Air Quality (CMAQ) model were used to calculate ozone concentrations for a base year in 2002 and a future year in 2009. Multiple analyses and sensitivity tests in this SIP (see Weight of Evidence Appendices, Appendix G-9 in particular) show that CMAQ is less responsive than it should be to changes in emissions. Be that as it may, in this appendix the outputs from CMAQ were evaluated with no consideration for any correction due to its demonstrated lack of response. Even by taking the outputs straight from CMAQ, the Baltimore nonattainment area should attain the 8-hour standard for ozone in 2009, with only one monitor having a future year design value as high as 85 ppbv. All other monitors are projected to fall well below 85 ppbv. As discussed in detail in Appendix G-9, CMAQ's underprediction of change means that Baltimore area ozone is likely to be well below the 8-hour standard in 2009. Results are discussed in the context of nearby nonattainment areas. The outlook is nearly as favorable for Washington, D.C., with two monitors projected to be one ppbv higher than the standard. The Philadelphia nonattainment area would appear to have a problem at first glance, with somewhat high future ozone concentrations predicted, but the CMAQ model's underprediction of change likely means that even the highest monitor should come into attainment. As discussed in Appendix G-9, by 2012, all monitors in the Northeast are predicted by CMAQ to be nearly in attainment. Given that CMAQ underpredicts changes in ozone, in 2012, the entire Northeast and Mid-Atlantic should be well below the 8-hour standard for ozone.

Introduction

In support of the Maryland attainment demonstration, the Community Multiscale Air Quality model (CMAQ) version 4.5 was used to model changes in Maryland's air quality for all the regulations that are already on the books or on the way (OTB/OTW) in 2009 and another scenario modeling the impact of those regulations plus an additional number of new local measures that go beyond on the books or on the way (Beyond OTB/OTW). The modeling is all performed in a relative sense, so that only fractional changes are calculated from the model. Those changes are then applied to base year design values for 8-hour ozone to generate future year predictions of ozone concentrations. 2002 was chosen as a base year for these calculations because it had a number of different types of ozone episodes, and had 38 days in which the 8-hour ozone concentration was greater than or equal to 85 ppbv. Therefore, in a future year, relatively few ozone episodes are expected to occur that are fundamentally different from those that occurred in 2002. The representativeness of 2002 as a base year was examined and found satisfactory [Stoeckenius and Kemball-Cook, 2005]. 2002 was also a useful year to model because it is a year in which emissions inventories must be generated and submitted to EPA as part of the normal three-year cycle.

Methods

CMAQ version 4.5.1 was used to simulate air quality for the entire year of 2002. Version 3.6 of Mesoscale Model 5 (MM5, the Penn State/NCAR mesoscale meteorological model) was used to simulate meteorology for the entire year. Four dimensional data assimilation was used to nudge MM5 back to observations continuously, so the fields generated using this technique do not suffer from the limitations of a weather forecast, but are in essence a reanalysis of weather patterns. Evaluation of the meteorological outputs of the MM5 model showed that they did a good, though, as expected, not perfect job of reproducing the meteorological conditions in 2002 [Zhang and Zheng, 2004; Hao, 2005; He, 2005; Zhang and Zhang, 2005; NYDEC, 2007a.] For example, temperature was very well correlated with National Weather Service observations, having a correlation between model and measurements that exceeded 0.9, with most above 0.96, at nearly all stations across the entire eastern United States for the entire summer of 2002. Relative humidity performance also very good, though not as outstanding as that for temperature, with correlation coefficients between 0.8 and 0.9, and wind speeds were correlated with observations, showing correlation coefficients between 0.7 and 0.8. Precipitation patterns were generally better reproduced in May and September than in June, July and August, owing to the generally convective nature of precipitation in the summer. The simulations also captured several incidences of the low-level jet.

The emissions inventories were put together by the states and the Regional Planning Organizations (RPOs). Inventories used in these simulations were put together by MANE-VU (Mid-Atlantic Northeast Visibility Union), VISTAS (Visibility Improvement State and Tribal Association of the Southeast), CENRAP (Central Regional Air Planning Association), and Midwest RPO (Midwest Regional Planning Organization, run by LADCO, Lake Michigan Air Directors Consortium). Point source emissions for these runs were projected to future years using IPM (Integrated Planning Model) run version 2.1.9 [EPA, 2005].

Emissions inventories are generally not in a format that can be used by CMAQ, because they are annual compilations of emissions on a county-by-county basis or on an even larger scale. As such, those inventories must be processed to generate the gridded, three-dimensional hourly emissions required by CMAQ. The processing is carried out using the SMOKE (Sparse Matrix Operator Kernel Emissions) emissions processor, which allocates emissions spatially and temporally, and puts them into a format that is acceptable to CMAQ [NYDEC 2007b, 2007c].

The simulations discussed in this appendix were all performed on the innermost, 12 km grid (Figure 1). This grid is nested inside a coarser continent-wide domain of 36 km resolution that extends to the West Coast of the U.S. The purpose of this larger domain is to generate reasonable background conditions to set up the simulations in the inner 12 km domain. No control strategies were applied to the outermost domain, so the boundary conditions reaching the inner 12 km domain were held constant. The boundary conditions for the 36 km domain were obtained from a global air quality model, as discussed elsewhere. As was the case with the 36 km domain, the global simulation was run only once, and no changes were assumed in any of its parameters [NYDEC 2007d].

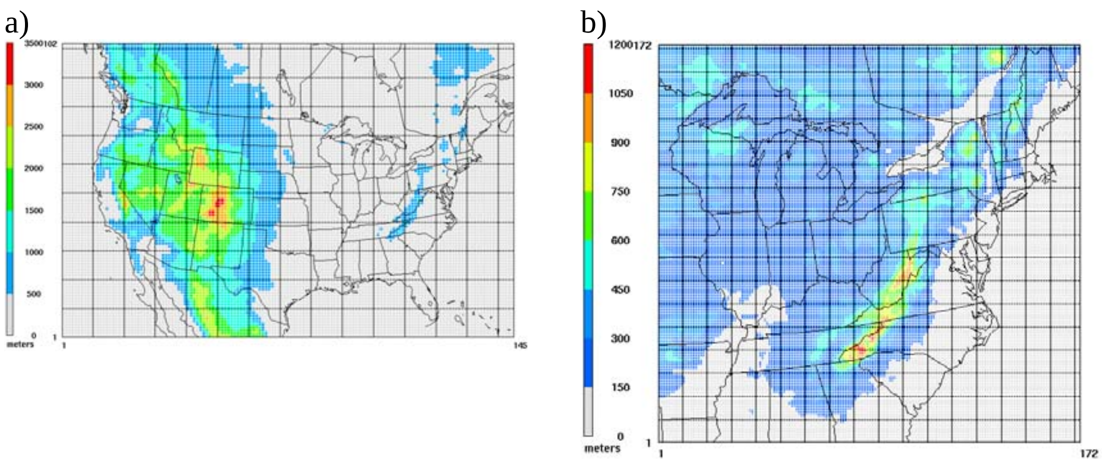

Figure 1. a) 36km and b) 12 km domains used in the CMAQ simulations run to support this SIP.

Further details of the setup of MM5, CMAQ, SMOKE, and the emissions inventories employed are available in other reports and the main body of this SIP [NYDEC, 2007a-h].

The CMAQ model's base case was evaluated against observations (see Appendix G-8, G-1, and G-9, NYDEC [2007e] and the main body of this SIP), and the performance meets EPA guidance for photochemical modeling. As noted in Appendix G-9, these performance goals have important shortcomings, such as difficulty in assessing the model's ability to capture ozone transport or respond to changes in emissions, which affect the results.

CMAQ was not used to predict absolute concentrations. Instead, relative changes between a base year and a future year were calculated from the model's output [NYDEC 2007g]. CMAQ produces numerical predictions for future year ozone levels, but these predictions suffer from errors associated with having to get every last detail of the meteorology and emissions correct. By using the relative predictions from the model, the issues instead become representativeness of the 2002 meteorology and the sensitivity of the photochemical model to changes in emissions. Using relative predictions from CMAQ eliminates or reduces many of the errors that plague forecasting efforts of all kinds. The relative (percentage or fractional) changes calculated between two CMAQ simulations (for a base year and a future year) are then multiplied by the base year design values to produce predictions of future year design values. Relative changes are calculated for high ozone days as projected in the model, following EPA guidance. For each monitor, future year modeled daily peak 8-hour ozone is checked to see if it exceeds 85 ppbv. If ten or more days in the future year feature modeled ozone in excess of 85 ppbv, then all those days are used to calculate the ratio between future and base year. If, as is quite often the case, there are not enough such days, then the threshold is lowered from 85 ppbv in 1 ppbv increments to 70 ppbv. If the threshold is lowered to 70 ppbv and ten days still do not exceed the threshold, then as few as five days are permissible. If there are still not enough days, meaning that the site is projected to be quite clean, then a future year design value is not calculated.

Future year simulations have been performed for 2009 and for 2012 and 2018 [NYDEC, 2007f], which show impressively clean conditions throughout the Northeast. By 2012, the entire Northeast falls within or below the “weight of evidence” range (83-87 ppbv), with the high monitors at 86 ppbv, and by 2018, CMAQ predicts compliance throughout the Northeast. By 2018, the highest monitor in the Northeast is below 83 ppbv (Middleport, NY, 82.8 ppbv).

Results

As discussed in other appendices of Chapter 11, CMAQ is an excellent tool, but it should be used with an understanding of its capabilities and shortcomings. In particular, its response to emissions changes (see Appendix G-9) suggests that modeled results should not be taken as the exact design values to be expected in 2009. These shortcomings are discussed in other appendices of Chapter 11, and will not be examined here. Instead, the results straight from CMAQ (using the relative reduction factor approach) are presented here in Table 1 for the Baltimore nonattainment area. Results from non-Baltimore monitoring locations are presented in Tables 2 and 3 for Washington, D.C. and Philadelphia, respectively to provide perspective on regional air quality.

The results from two scenarios are presented in this section: a straightforward 2009 on-the-books and on-the-way (OTB/OTW) simulation and a 2009 Beyond OTB/OTW simulation that includes the benefits from additional local measures.

Table 1. Current and future year design values as calculated by CMAQ at monitors throughout the Baltimore nonattainment area. CMAQ predictions for 2009 have been truncated to remove the decimal point.

Site Name	Site Number	2002 Design Value	2009 OTB/OTW	2009 Beyond OTB/OTW
Davidsonville Anne Arundel Co., MD	240030014	98.0	84	84

Ft. Meade Anne Arundel Co., MD	240030019	97.0	84	84
Padonia Baltimore Co., MD	240051007	88.7	77	77
Essex Baltimore Co., MD	240053001	91.3	80	80
South Carroll Baltimore Co., MD	240130001	88.7	75	75
Edgewood Harford Co., MD	240251001	100.3	85	85
Aldino Harford Co., MD	240290003	97.0	82	82

Table 2. Current and future year design values as calculated by CMAQ at monitors throughout the Washington, D.C. nonattainment area. CMAQ predictions for 2009 have been truncated to remove the decimal point.

Site Name, County and State	Site Number	2002 Design Value	2009 OTB/OTW	2009 Beyond OTB/OTW
Takoma Park Washington, D.C.	110010025	88.7	79	79
River Terrace Washington, D.C.	110010041	89	82	82
McMillan Reservoir Washington, D.C.	110010043	92.7	79	79
Southern Maryland Charles Co., MD	240170010	93	76	75
Frederick Airport Frederick Co., MD	240210037	87.3	74	73
Rockville Montgomery Co., MD	240313001	86.7	76	76
Greenbelt* Prince George's Co., MD	240330002	94	82	81
Prince George’s Eq. Ctr. Prince George’s Co., MD	240338003	94	81	81
Arlington Arlington Co., VA	510130020	96.7	86	86
Chantilly Fairfax Co., VA	510590005	87	75	75

Mt Vernon Fairfax Co., VA	510590018	96.7	86	86
Lee Park Fairfax Co., VA	510590030	95	84	84
Annandale Fairfax Co., VA	510591005	94	83	83
McLean Fairfax Co., VA	510595001	88	77	77
Frederick Frederick Co., VA	510690010	82.7	72	71
Loudon Loudon Co., VA	511071005	90	78	78
Prince William Prince William Co., VA	511530009	85	74	74
Alexandria City Alexandria Co., VA	515100009	90	80	80

*Monitor discontinued in 2003 due to loss of permission to use location.

Table 3. Current and future year design values as calculated by CMAQ at monitors throughout the Philadelphia nonattainment area. CMAQ predictions for 2009 have been truncated to remove the decimal point.

Site Name, County and State	Site Number	2002 Design Value	2009 OTB/OTW	2009 Beyond OTB/OTW
Fair Hill Cecil Co., MD	240150003	97.7	81	81
Brandywine Creek New Castle Co., DE	100031010	92.7	81	81
Bellefonte New Castle Co., DE	100031013	90.3	79	78
Killens Pond Kent Co., DE	100010002	88.3	78	78
Lewes New Castle Co., DE	100051003	87.0	77	77
Lums Pond New Castle Co., DE	100031007	94.5	79	79
Seaford Sussex Co., DE	100051002	90.0	76	75

Colliers Mills Ocean Co., NJ	340290006	106.0	92	92
Rider Mercer Co., NJ	340210005	97.0	86	86
Ancora State Hospital Camden Co., NJ	340071001	100.7	87	87
Camden Camden Co., NJ	340070003	98.3	88	88
Clarksboro Gloucester Co., NJ	340155001	98.3	88	88
Millville Cumberland Co., NJ	340110007	95.7	81	81
Nacote Creek Atlantic Co., NJ	340010005	89.0	77	77
Bristol Bucks Co., PA	420170012	99.0	88	88
West Chester Chester Co., PA	420290050	95.0	82	82
New Garden Chester Co., PA	420290100	94.7	79	79
Chester Delaware Co., PA	420450002	91.7	81	81
Norristown Montgomery Co., PA	420910013	92.3	81	81
Elmwood Philadelphia Co., PA	421010136	83.0	75	75
Lab Philadelphia Co., PA	421010004	71.3	64	64
Roxborough Philadelphia Co., PA	421010014	90.7	82	82
Northeast Airport Philadelphia Co., PA	421010024	96.7	87	87

Throughout the Baltimore nonattainment area, the picture for future ozone in 2009 is quite positive, even using projections directly from the CMAQ model. The highest monitor in the region is the Edgewood monitor, which is not surprising, since its 2002 design value was also the highest in the Baltimore nonattainment area. Edgewood is in a somewhat unusual location, being right near a body of water that is not represented in the MM5 meteorological model, and consequently not represented in CMAQ. This is a straightforward issue of model resolution; a 12 km grid cell cannot reproduce phenomena on scales smaller than that. Therefore, the things that make Edgewood an unusual monitor in reality (see Appendix G-11) are likely not well represented in CMAQ. CMAQ predicts that Edgewood will become remarkably cleaner in 2009. Regardless, as discussed in Appendix G-10 and G-9, future ozone values at all Baltimore monitors will likely be considerably lower than those presented here. In nearby Washington, D.C., the ozone picture is almost as favorable, with CMAQ predicting only two monitors in Northern Virginia at all higher than the 85 ppv standard, at 86 ppbv. Downwind of Philadelphia lies the challenging Colliers Mills monitor, which CMAQ predicts at 92 ppbv.

The Beyond OTB/OTW simulation also presented in Tables 1, 2, and 3 shows that because Federal programs like CAIR, heavy duty diesels, and Tier II vehicle standards take care of the biggest source categories, relatively little NO_x remains to be addressed in the inventory. This simulation addresses the additional impacts of several local measures that have been added to the larger Federal programs. More importantly, what NO_x remains is divided among many diverse categories. This is a reflection of the nature of sources throughout the Northeast, namely that the bulk of the NO_x emissions come from point sources and mobile sources (off road and on road). As seen in the table below, the additional local programs net roughly one ppbv additional ozone reduction. Most of the benefits of this suite of local programs are hidden by the rounding convention used in presenting the results. These programs are likely to have benefits outside of ozone reductions, so their contribution is not to be minimized, but purely from an ozone standpoint, their contributions are smaller than those from larger, federally mandated programs. The telecommuting scenario discussed in Appendix G-14 is not included in any scenario modeled in this appendix.

The emissions changes from the OTB/OTW and Beyond OTB/OTW scenarios are given below in Tables 4a and 4b [MACTEC, 2007a]. Details of the development of these emissions inventories are given in MACTEC [2007a, b]. EGU (Electrical Generating Unit) point source inventories were projected to future years using the Integrated Planning Model (IPM) [EPA, 2005].

Table 4a. Summary of MANE-VU Area, Non-EGU, and Non-road Emission Inventories for 2009 by Pollutant, Sector, and Year (tons per year)

Pollutant	Sector	2002	2009 OTB/OTW	2009 BOTB/OTW
CO	Area	1,326,796	1,283,959	1,283,959
	NonEGU	295,577	328,546	328,546
	Nonroad	4,553,124	4,969,925	4,969,925
		6,175,497	6,582,430	6,582,430
NH_3	Area	249,795	294,934	294,934
	NonEGU	3,916	4,301	4,301
	Nonroad	287	317	317
		253,998	299,552	299,552
NO_x	Area	265,400	278,038	265,925
	NonEGU	207,048	210,522	185,658
	Nonroad	431,631	354,850	354,850

		904,079	843,410	806,433
PM10	Area	1,452,309	1,527,586	1,527,586
	NonEGU	51,280	55,869	55,869
	Nonroad	40,114	34,453	34,453
		1,543,703	1,617,908	1,617,908
PM2.5	Area	332,521	340,049	340,049
	NonEGU	33,077	36,497	36,497
	Nonroad	36,084	30,791	30,791
		401,682	407,337	407,337
SO_2	Area	286,921	304,018	304,018
	NonEGU	264,377	249,658	249,658
	Nonroad	57,257	15,651	15,651
		608,555	569,327	569,327
VOC	Area	1,528,269	1,398,982	1,363,278
	NonEGU	91,278	92,279	91,718
	Nonroad	572,751	460,922	460,922
		2,192,298	1,952,183	1,915,918

Table 4b. Summary of MANE-VU Area, Non-EGU, and Nonroad Emission Inventories for 2012 and 2018 by Pollutant, Sector, and Year (tons per year)

Pollutant	Sector	2012 OTB/OTW	2012 BOTB/OTW	2018 OTB/OTW	2018 BOTB/OTW
CO	Area	1,260,627	1,260,627	1,211,727	1,211,727
	NonEGU	346,090	346,090	412,723	412,723
	Nonroad	5,099,538	5,099,538	5,401,353	5,401,353
		6,706,255	6,706,255	7,025,803	7,025,803
NH_3	Area	312,419	312,419	341,746	341,746
	NonEGU	4,448	4,448	4,986	4,986
	Nonroad	337	337	369	369
		317,204	317,204	347,101	347,101
NO_x	Area	281,659	261,057	284,535	263,030
	NonEGU	218,137	184,527	237,802	199,732
	Nonroad	321,935	321,935	271,185	271,185
		821,731	767,519	793,522	733,947
PM10	Area	1,556,316	1,550,400	1,614,476	1,607,602
	NonEGU	57,848	57,624	63,757	63,524
	Nonroad	32,445	32,445	27,059	27,059
		1,646,609	1,640,469	1,705,292	1,698,185
PM2.5	Area	341,875	336,779	345,419	339,461
	NonEGU	37,625	37,444	41,220	41,029
	Nonroad	28,922	28,922	23,938	23,938
		408,422	403,145	410,577	404,428
SO_2	Area	305,339	202,058	305,437	190,431
	NonEGU	255,596	253,638	270,433	268,330

	Nonroad	8,731	8,731	8,643	8,643
		569,666	464,427	584,513	467,404
VOC	Area	1,382,803	1,339,851	1,387,882	1,334,039
	NonEGU	96,887	96,260	110,524	109,762
	Nonroad	424,257	424,257	380,080	380,080
		1,903,947	1,860,368	1,878,486	1,823,881

Controls for different sectors of the OTB/OTW scenario were implemented for each source category. Emissions from all source categories were grown using an economic and activity model as documented in [MACTEC, 2007a] except for aircraft, commercial marine, and locomotive sources. For aircraft, commercial marine and locomotive sources, throughout all the OTC except Maryland, emissions were interpolated from CAIR inventories for 2001, 2010, 2015 and 2020 to the MANE-VU years of 2009, 2012 and 2018. Maryland emissions were developed using the EGAS economic model and federal control programs. Other non-road emissions were projected using the NONROAD model, as incorporated into the new NMIM model (National Mobile Inventory Model). Mobile emissions were predicted using the MOBILE part of that model. For some categories, such as EGUs and mobile sources, the reductions come largely from big federal programs such as the NOx SIP Call. For Non-EGU point sources and area sources, the control measures are listed below. EGU controls were similar, but with the exclusion of controls that do not apply to EGUs. Federal Tier I and Tier II motor vehicle standards were used for mobile sources, and the suite of federal programs were applied to non-road sources such as railroads, airplanes, lawn and garden equipment, and airport maintenance vehicles as documented in [MACTEC, 2007a].

Non-EGU Point Source Control Measures (OTB/OTW)

- NOx SIP Call Phase I (NOx Budget Trading Program)
- NOx SIP Call Phase II
- NOx RACT in 1-hour Ozone SIPs
- NOx OTC 2001 Model Rule for ICI Boilers
- 2-, 4-, 7-, and 10-year MACT Standards
- Combustion Turbine and RICE MACT
- Industrial Boiler/Process Heater MACT
- Refinery Enforcement Initiative
- Source Shutdowns

Area Source Control Measures

- OTC VOC Model Rules
- Federal On-board Vapor Recovery
- New Jersey Post-2002 Area Source Controls
- Residential Woodstove NSPS

Implementation of controls across different sectors for the BOTB/OTW scenario varied by state and year. The impacts and timing of those controls, are detailed in MACTEC [2007a, b]. Briefly, the areas considered for controls in the BOTB/OTW scenario are:

Consumer products
Portable fuel containers
Adhesives and sealants application
Diesel engine chip reflash
Cutback and emulsified asphalt paving
Asphalt production plants
Cement kilns
Glass furnaces
Industrial, commercial, and institutional (ICI) boilers
Regional fuels
Electrical generating units (EGUs)

By 2012, ozone levels are greatly reduced, with the effects of CAIR and motor vehicle fleet turnover being seen. The highest design values are all 86 ppb, shared at the Colliers Mills monitor and two others in the New York City nonattainment area (Table 5). By 2018, all ozone monitors throughout the OTR are projected by CMAQ to be well into attainment, with none higher than 83 ppbv (Table 6).

Table 5. Design Values for 2002 and projected design values for 2012 as calculated by CMAQ.

County	Monitor	Site Number	2002 Design Value	2012 Design Value
Fairfield	Greenwich	90010017	95.7	83
Fairfield	Danbury	90011123	95.7	81
Fairfield	Stratford	90013007	98.3	86
Fairfield	Westport	90019003	94.0	81
Hartford	E. Hartford	90031003	88.0	72
Litchfield	Cornwall	90050005	89.0	72
Middlesex	Middletown	90070007	95.7	80
New Haven	Madison	90093002	98.3	83
New Haven	Hamden	90099005	93.3	81
New London	Groton	90110008	90.0	74
Tolland	Stafford	90131001	92.3	75
Kent	Killens Pond	100010002	88.3	74
New Castle	Lums Pond	100031007	94.5	74
New Castle	Brandywine	100031010	92.7	76
New Castle	Bellefonte	100031013	90.3	74
Sussex	Seaford	100051002	90.0	70
Sussex	Lewes	100051003	87.0	74
Washington, D.C.	Takoma Park	110010025	88.7	73
Washington, D.C.	River Terrace	110010041	89.0	73
Washington, D.C.	McMillan Res	110010043	92.7	76
Aroostook	Ashland	230038001	64.0	
Cumberland	Cape Elizabeth	230052003	84.3	69
Hancock	ANP Cadillac	230090102	91.7	75

Hancock	ANP McFarland	230090103	83.7	68
Hancock	Castine	230090301	75.0	62
Kennebec	Gardiner Pray	230112005	78.0	63
Knox	Port Clyde	230130004	83.7	68
Oxford	North Lovell	230173001	60.7	
Penobscot	Howland	230194007	66.7	
Penobscot	Holden Rider	230194008	79.0	
York	West Buxton	230310038	75.0	60
York	Kennebunkport	230312002	88.3	72
York	Kittery	230313002	85.3	69
Anne Arundel	Davidsonville	240030014	98.0	78
Anne Arundel	Ft. Meade	240030019	97.0	78
Baltimore	Padonia	240051007	88.7	72
Baltimore	Essex	240053001	91.3	76
Carroll	South Carroll	240130001	88.7	69
Cecil	Fair Hill	240150003	97.7	75
Charles	S Maryland	240170010	93.0	70
Frederick	Frederick Airp	240210037	87.3	68
Harford	Edgewood	240251001	100.3	80
Harford	Aldino	240259001	97.0	76
Kent	Millington	240290002	95.3	74
Montgomery	Rockville	240313001	86.7	71
Prince Georges	Greenbelt	240330002	94.0	76
Prince Georges	PG Co. Eques.	240338003	94.0	76
Washington	Hagerstown	240430009	85.3	67
Barnstable	Truro	250010002	92.0	75
Berkshire	Adams	250034002	83.3	68
Bristol	Fairhaven	250051002	91.0	75
Essex	Lawrence	250090005	70.0	58
Essex	Lynn	250092006	90.0	79
Essex	Newbury	250094004	86.0	71
Hampden	Agawam	250130003	83.0	68
Hampden	Chicopee	250130008	92.0	75
Hampshire	Amherst	250150103	74.7	61
Hampshire	Ware	250154002	86.3	70
Middlesex	Stow	250171102	85.7	70
Norfolk	Milton	250213003	91.0	79
Suffolk	Boston (Long I)	250250041	88.7	77
Suffolk	Boston (Harris)	250250042	73.0	63
Worcester	Worcester	250270015	84.0	67
Belknap	Laconia	330012004	76.5	
Carroll	Conway	330031002	67.0	
Cheshire	Keene	330050007	74.3	60
Grafton	Haverhill	330090008	70.3	
Hillsborough	Nashua	330111010	86.0	70
Hillsborough	Peterborough	330115001	84.0	69

Merrimack	Concord	330130007	74.7	
Rockingham	Rye	330150012	83.5	68
Rockingham	—	330150013	80.0	64
Rockingham	Portsmouth	330150015	68.0	55
Strafford	Rochester	330173002	78.5	63
Sullivan	Claremont	330190003	74.3	
Atlantic	Nacote Creek	340010005	89.0	73
Bergen	Teaneck	340030005	91.7	81
Camden	Camden	340070003	98.3	83
Camden	Ancora St. Hos	340071001	100.7	82
Cumberland	Millville	340110007	95.7	75
Gloucester	Clarksboro	340155001	98.3	83
Hudson	Bayonne	340170006	84.7	75
Hunterdon	Flemington	340190001	95.3	78
Mercer	Rider Univ.	340210005	97.0	81
Middlesex	Rutgers Univ.	340230011	96.0	79
Monmouth	Monmouth U.	340250005	95.7	80
Morris	Chester	340273001	95.3	79
Ocean	Colliers Mills	340290006	106.0	86
Passaic	Ramapo	340315001	86.7	73
Albany	Loudonville	360010012	83.0	70
Bronx	Botanical Gard	360050083	83.7	75
Chautauqua	Dunkirk	360130006	93.0	76
Chautauqua	Westfield	360130011	87.0	72
Chemung	Elmira	360150003	80.3	
Dutchess	Millbrook	360270007	92.0	76
Erie	Amherst	360290002	95.7	80
Essex	Whiteface Sum	360310002	88.3	
Essex	Whiteface Base	360310003	84.3	
Hamilton	Piseco Lake	360410005	78.7	
Herkimer	Nick's Lake	360430005	74.0	63
Jefferson	Perch River	360450002	91.3	77
Madison	C. Georgetown	360530006	79.7	
Monroe	Rochester	360551004	83.7	72
Niagara	Middleport	360631006	91.7	79
Oneida	Camden	360650004	79.7	66
Onondoga	East Syracuse	360671015	82.3	70
Orange	Valley Central	360715001	84.7	68
Putnam	Mt. Ninham	360790005	91.3	77
Queens	Queens College	360810124	83.0	71
Richmond	Susan Wagner	360850067	93.0	80
Saratoga	Stillwater	360910004	84.7	69
Suffolk	Babylon	361030002	93.7	82
Suffolk	Riverhead	361030004	83.0	70
Suffolk	Holtsville	361030009	97.0	86
Ulster	Belleayre	361111005	81.3	

Wayne	Williamson	361173001	84.0	71
Westchester	White Plains	361192004	91.3	82
Adams	Biglerville	420010002	85.0	67
Allegheny	Lawrenceville	420030008	89.3	76
Allegheny	Pittsburgh	420030010	90.7	77
Allegheny	South Fayette	420030067	89.3	75
Allegheny	Harrison Twp	420031005	91.3	74
Armstrong	Kittanning	420050001	90.7	72
Beaver	Hookstown	420070002	91.3	73
Beaver	Brighton Twp	420070005	89.7	73
Beaver	Beaver Falls	420070014	85.0	68
Berks	Kutztown	420110001	84.5	67
Berks	Reading	420110009	88.7	71
Blair	Altoona	420130801	83.3	66
Bucks	Bristol	420170012	99.0	84
Cambria	Johnstown	420210011	85.0	67
Centre	State College	420270100	84.3	66
Centre	Penn Nursery	420274000	84.7	67
Chester	West Chester	420290050	95.0	77
Chester	New Garden	420290100	94.7	73
Clearfield	Moshannon	420334000	87.3	67
Dauphin	Harrisburg	420430401	85.0	66
Dauphin	Hershey	420431100	86.7	68
Delaware	Chester	420450002	91.7	77
Erie	Erie	420490003	89.0	73
Franklin	Methodist Hill	420550001	90.7	71
Greene	Holbrook	420590002	87.7	70
Lacakawana	Peckville	420690101	83.3	66
Lacakawana	Scranton	420692006	82.0	65
Lancaster	Lancaster	420710007	90.7	72
Lawrence	New Castle	420730015	78.3	61
Lehigh	Allentown	420770004	90.7	74
Luzerene	Nanticoke	420791100	81.7	64
Luzerene	Wilkes-Barre	420791101	83.7	65
Lycoming	Montoursville	420810100	82.0	65
Lycoming	Tiadaghton	420814000	78.7	61
Mercer	Farrell	420850100	91.3	73
Montgomery	Norristown	420910013	92.3	77
Northampton	Freemansburg	420950025	90.0	73
Northampton	Easton	420958000	88.0	71
Perry	Perry County	420990301	83.3	65
Philadelphia	Frankford (Lab)	421010004	71.3	61
Philadelphia	Northwest (Rox)	421010014	90.7	78
Philadelphia	Northeast (Air)	421010024	96.7	82
Philadelphia	Southwest (Elm)	421010136	83.0	71
Tioga	Tioga County	421174000	85.0	68

Washington	Charleroi	421250005	86.3	72
Washington	Washington	421250200	85.3	68
Washington	Florence	421255001	85.7	67
Wetsmoreland	Murrysville	421290006	82.0	69
Westmoreland	Greensburg	421290008	88.0	73
York	York	421330008	89.0	71
Kent	Alton Jones	440030002	93.3	75
Providence	Francis School	440071010	89.7	73
Washington	EPA Lab	440090007	93.3	77
Bennington	Bennington	500030004	79.7	66
Chittenden	Underhill	500070007	77.0	
Arlington	Arlington Co.	510130020	96.7	80
Caroline	Caroline Co.	510330001	82.3	64
Charles City	Charles City C	510360002	89.3	74
Chesterfield	Chesterfield C	510410004	84.7	69
Fairfax	Fairfax Co.	510590005	87.0	68
Fairfax	Fairfax Co.	510590018	96.7	79
Fairfax	Fairfax Co.	510590030	95.0	77
Fairfax	Fairfax Co.	510591005	94.0	77
Fairfax	Fairfax Co.	510595001	88.0	71
Fauqier	Fauquier Co.	510610002	79.3	62
Frederick	Frederick Co.	510690010	82.7	68
Hanover	Hanover Co.	510850003	92.0	74
Henrico	Henrico Co.	510870014	88.3	72
Loudon	Loudoun Co.	511071005	90.0	71
Madison	Madison Co.	511130003	84.7	68
Page	Page Co.	511390004	79.7	63
Prince William	Prince William	511530009	85.0	68
Roanoke	Roanoke Co.	511611004	83.7	68
Rockbridge	Rockbridge Co.	511630003	76.7	61
Stafford	Stafford Co.	511790001	86.0	68
Wythe	Wythe Co.	511970002	79.7	
Alexandria Cit	Alexandria	515100009	90.0	74
Hampton City	Hampton	516500004	88.3	78
Suffolk City	Suffolk - TCC	518000004	87.0	79
Suffolk City	Suffolk - Holl	518000005	82.3	66
—	Roosevelt-Camp	CC0040002	58.3	49

Table 6. Current and Future Design Values Across the OTR for 2002, and projections by CMAQ for 2009 and 2018.

Description	Site	2002 Design Value	2009 OTB/OTW	2009 BOTB/OTW	2018
Greenwich	90010017	95.7	87.6	87.4	81.4
Danbury	90011123	95.7	86.1	85.8	78.4
Stratford	90013007	98.3	90.6	90.3	82.7

Westport	90019003	94.0	85.6	85.5	78.8
E. Hartford	90031003	88.0	77.4	77.1	68.1
Cornwall	90050005	89.0	77.8	77.4	68.4
Middletown	90070007	95.7	85.4	85.0	76.5
Madison	90093002	98.3	89.3	89.0	80.7
Hamden	90099005	93.3	85.4	85.1	79.4
Groton	90110008	90.0	79.5	79.1	70.3
Stafford	90131001	92.3	80.5	80.0	70.7
Killens Pond	100010002	88.3	78.9	78.7	70.6
Lums Pond	100031007	94.5	80.0	79.7	69.6
Brandywine	100031010	92.7	81.4	81.1	73.2
Bellefonte	100031013	90.3	79.1	78.8	70.0
Seaford	100051002	90.0	76.1	75.9	65.9
Lewes	100051003	87.0	78.0	77.7	70.7
Takoma Park	110010025	88.7	79.4	79.3	69.2
River Terrace	110010041	89.0	79.2	79.0	68.4
McMillan Res.	110010043	92.7	82.5	82.3	71.3
Cape Elizabeth	230052003	84.3	73.7	73.6	66.3
ANP Cadillac Mtn.	230090102	91.7	79.9	79.7	70.3
ANP McFarland	230090103	83.7	73.0	72.9	64.2
Castine	230090301	75.0	65.9	65.9	58.0
Gardiner Pray	230112005	78.0	68.0	67.8	60.6
Port Clyde	230130004	83.7	73.1	72.9	64.6
Holden Rider	230194008	79.0			61.2
West Buxton	230310038	75.0	64.7	64.5	56.4
Kennebunkport	230312002	88.3	77.4	77.3	68.3
Kittery	230313002	85.3	74.3	74.1	67.1
Davidsonville	240030014	98.0	84.3	84.1	72.5
Fort Meade	240030019	97.0	84.5	84.3	72.6
Padonia	240051007	88.7	77.5	77.4	68.3
Essex	240053001	91.3	80.4	80.3	73.0
South Carroll	240130001	88.7	75.7	75.1	64.5
Fair Hill	240150003	97.7	81.5	81.2	70.3
S. Md (Hughesville)	240170010	93.0	76.2	75.9	65.4
Frederick Apt	240210037	87.3	74.9	73.9	64.8
Edgewood	240251001	100.3	85.7	85.5	76.9
Aldino	240259001	97.0	82.4	82.1	72.9
Millington	240290002	95.3	80.2	79.9	70.8
Rockville	240313001	86.7	76.7	76.6	65.8
Greenbelt	240330002	94.0	82.2	82.0	70.9
PG Equestrian Ctr	240338003	94.0	81.8	81.6	70.9
Hagerstown	240430009	85.3	73.1	72.1	63.7
Truro	250010002	92.0	80.9	80.7	71.9
Adams	250034002	83.3	73.4	73.1	65.2
Fairhaven	250051002	91.0	80.3	79.9	71.2
Lawrence	250090005	70.0	61.8	61.6	55.7

Lynn	250092006	90.0	82.6	82.4	79.6
Newbury	250094004	86.0	76.0	75.9	68.9
Agawam	250130003	83.0	72.9	72.5	62.7
Chicopee	250130008	92.0	80.7	80.2	69.1
Amherst	250150103	74.7	65.6	65.3	57.9
Ware	250154002	86.3	75.7	75.3	65.4
Stow	250171102	85.7	75.0	74.6	65.8
Milton	250213003	91.0	83.2	82.9	78.3
Boston (Long I)	250250041	88.7	80.8	80.6	76.9
Boston (Harris)	250250042	73.0	66.4	66.3	64.0
Worcester	250270015	84.0	72.8	72.5	64.6
Laconia	330012004	76.5			57.9
Keene	330050007	74.3	64.6	64.3	56.3
Nashua	330111010	86.0	74.9	74.6	65.5
Peterborough	330115001	84.0	73.7	73.3	64.7
Rye	330150012	83.5	72.7	72.6	65.7
—	330150013	80.0	68.8	68.6	60.2
Portsmouth	330150015	68.0	59.2	59.1	53.5
Rochester	330173002	78.5	67.8	67.5	59.4
Nacote Creek	340010005	89.0	78.0	77.8	69.3
Teaneck 1000	340030005	91.7	85.3	85.1	80.8
Camden Lab	340070003	98.3	88.5	88.3	80.5
Ancora Hospital	340071001	100.7	87.9	87.8	78.6
Millville	340110007	95.7	81.3	81.1	71.9
Clarksboro	340155001	98.3	88.5	88.3	80.3
Bayonne Park	340170006	84.7	77.2	77.2	77.0
Flemington	340190001	95.3	83.9	83.6	73.2
Rider U	340210005	97.0	86.4	86.2	76.8
Rutgers U	340230011	96.0	84.1	83.9	73.5
Monmouth U	340250005	95.7	84.3	84.2	75.6
Chester Bldg	340273001	95.3	84.3	84.1	74.1
Colliers Mills	340290006	106.0	92.2	92.0	81.3
Ramapo Acc Rd	340315001	86.7	78.0	77.9	70.4
Loudonville	360010012	83.0	74.6	73.9	67.6
Botanical Gard	360050083	83.7	78.6	78.6	76.3
Dunkirk	360130006	93.0	81.7	81.5	72.9
Westfield	360130011	87.0	76.6	76.5	68.1
Elmira	360150003	80.3			62.5
Millbrook	360270007	92.0	81.1	80.9	69.6
Amherst	360290002	95.7	84.6	84.6	79.9
Nick's Lake	360430005	74.0	64.7	64.6	64.2
Perch River	360450002	91.3	80.3	80.0	78.7
Rochester	360551004	83.7	75.2	74.9	70.9
Middleport	360631006	91.7	82.1	81.9	82.8
Camden	360650004	79.7	69.3	69.1	67.8
East Syracuse	360671015	82.3	73.7	73.2	67.0

Valley Central	360715001	84.7	73.7	73.5	65.0
Mt. Ninham	360790005	91.3	82.1	81.7	73.3
Queens College	360810124	83.0	74.3	74.2	70.6
Susan Wagner	360850067	93.0	84.2	84.1	78.5
Stillwater	360910004	84.7	74.4	73.6	65.5
Babylon	361030002	93.7	85.9	85.9	82.1
Riverhead	361030004	83.0	75.0	74.8	67.7
Holtsville	361030009	97.0	90.0	89.8	82.6
Belleayre	361111005	81.3			64.7
Williamson	361173001	84.0	74.7	74.4	69.8
White Plains	361192004	91.3	85.5	85.4	81.6
Biglerville	420010002	85.0	73.8	71.2	64.9
Lawrenceville	420030008	89.3	80.4	80.2	74.2
Pittsburgh	420030010	90.7	81.6	81.5	75.4
South Fayette	420030067	89.3	80.3	80.1	73.7
Harrison Twp	420031005	91.3	78.9	78.7	70.7
Kittanning	420050001	90.7	77.6	77.5	69.2
Hookstown	420070002	91.3	81.3	81.2	72.9
Brighton Twp	420070005	89.7	78.6	78.4	71.0
Beaver Falls	420070014	85.0	73.8	73.6	66.6
Kutztown	420110001	84.5	72.5	72.0	62.5
Reading	420110009	88.7	76.4	75.8	66.4
Altoona	420130801	83.3	69.7	69.6	63.2
Bristol	420170012	99.0	88.9	88.7	79.7
Johnstown	420210011	85.0	71.7	71.5	65.5
State College	420270100	84.3	70.7	70.2	63.6
Penn Nursery	420274000	84.7	72.0	71.4	64.6
West Chester	420290050	95.0	82.8	82.5	70.5
New Garden	420290100	94.7	79.5	79.1	68.2
Moshannon (PSU)	420334000	87.3	72.2	71.9	64.4
Harrisburg	420430401	85.0	73.3	71.5	64.1
Hershey	420431100	86.7	74.3	73.3	64.0
Chester	420450002	91.7	81.3	81.2	74.2
Erie	420490003	89.0	78.3	78.2	70.0
Methodist Hill	420550001	90.7	77.0	76.3	66.7
Holbrook	420590002	87.7	75.3	75.0	63.7
Peckville	420690101	83.3	71.5	70.7	61.4
Scranton	420692006	82.0	70.4	69.6	60.4
Lancaster	420710007	90.7	77.4	76.5	68.5
New Castle	420730015	78.3	66.5	66.4	58.7
Allentown	420770004	90.7	78.9	78.6	69.1
Nanticoke	420791100	81.7	69.0	68.6	59.3
Wilkes-Barre	420791101	83.7	70.6	70.1	60.9
Montoursville	420810100	82.0	69.8	69.3	60.8
Tiadaghton	420814000	78.7	65.9	65.5	57.8
Farrell	420850100	91.3	77.6	77.6	68.1

Norristown	420910013	92.3	81.8	81.5	73.4
Freemansburg	420950025	90.0	78.7	78.3	68.9
Easton	420958000	88.0	76.8	76.5	67.3
Perry County	420990301	83.3	71.1	70.1	62.8
Frankford (Lab)	421010004	71.3	64.7	64.6	58.5
Northwest (Rox)	421010014	90.7	82.8	82.6	74.5
Northeast (Air)	421010024	96.7	87.3	87.1	79.0
Southwest (Elm)	421010136	83.0	75.3	75.1	68.2
Tioga County	421174000	85.0	73.0	72.8	64.9
Charleroi	421250005	86.3	76.2	75.9	68.7
Washington	421250200	85.3	73.4	73.2	64.1
Florence	421255001	85.7	74.4	74.3	66.8
Murrysville	421290006	82.0	73.0	72.7	66.4
Greensburg	421290008	88.0	77.5	77.3	69.5
York	421330008	89.0	77.1	75.9	68.3
Alton Jones	440030002	93.3	80.8	80.4	70.6
Francis School	440071010	89.7	78.2	77.9	68.7
EPA Lab	440090007	93.3	82.0	81.7	72.6
Bennington	500030004	79.7	70.8	70.4	63.4
Arlington Co.	510130020	96.7	86.7	86.6	75.2
Caroline Co.	510330001	82.3	70.1	70.0	57.7
Charles City	510360002	89.3	80.4	80.3	74.2
Chesterfield	510410004	84.7	75.6	75.6	70.2
Chantilly	510590005	87.0	75.8	75.6	64.5
Mt. Vernon	510590018	96.7	86.3	86.2	74.9
Lee Park	510590030	95.0	84.3	84.2	73.5
Annandale	510591005	94.0	83.4	83.3	72.8
McLean	510595001	88.0	78.0	77.9	67.9
Fauquier Co.	510610002	79.3	67.6	67.4	58.5
Frederick Co.	510690010	82.7	72.2	71.9	65.7
Hanover Co.	510850003	92.0	81.5	81.4	73.9
Henrico Co.	510870014	88.3	78.9	78.8	72.1
Loudoun Co.	511071005	90.0	78.5	78.3	68.6
Madison Co.	511130003	84.7	71.6	71.5	61.9
Page Co.	511390004	79.7	67.3	67.1	59.2
Prince William	511530009	85.0	74.5	74.2	64.7
Roanoke Co.	511611004	83.7	73.1	73.0	63.7
Rockbridge Co.	511630003	76.7	65.7	65.6	57.1
Stafford Co.	511790001	86.0	75.5	75.3	62.1
Wythe Co.	511970002	79.7			59.5
Alexandria	515100009	90.0	80.3	80.2	69.7
Hampton	516500004	88.3	83.0	82.9	77.2
Suffolk - TCC	518000004	87.0	82.9	82.8	77.8
Suffolk - Holl	518000005	82.3	72.3	72.1	65.4

Conclusions

Even by taking relative reduction factors and the resulting predictions of 8-hour ozone concentrations straight from CMAQ, with no consideration for CMAQ's tendency to underpredict future changes in ozone due to emissions changes, the Baltimore Non-Attainment Area is very close to attaining the 8-hour standard for ozone, with the high monitor in the region having a predicted 2009 design value of 85 ppbv. As discussed in detail in Appendix G-9, the Baltimore Non-Attainment Area is likely to be in compliance with the 8-hour standard, owing to CMAQ's resistance to change. Some areas for improvement in CMAQ's chemical mechanism are outlined in Appendix G-10. The picture is nearly as favorable for the Washington, D.C. Non-Attainment Area, with two monitors one ppbv higher than the standard. The Philadelphia Non-Attainment Area would appear to have a problem at first glance, but the CMAQ model's resistance to change likely overpredicts future ozone by a margin such that even the Colliers Mills monitor should come into attainment. As discussed above and in Appendix G-9, by 2012, all monitors in the Northeast are predicted by CMAQ to be nearly in attainment, if not entirely so.

Future Work

This appendix, in conjunction with Appendix G-10 and G-9, suggests the need to improve the chemical mechanism of CMAQ. In the near term, using the SAPRC99 chemical mechanism in place of the CB4 chemical mechanism that was used for these simulations would serve as a potential stopgap measure. In the longer term, one of the many implementations of WRF-CHEM (Weather Research and Forecasting model with chemistry) appears to have a more responsive chemical mechanism. The computational cost of running WRF-CHEM is substantial because both meteorology and chemistry are simulated at once, but the additional time might be worthwhile if the change in ozone in response to emissions changes could be predicted more realistically. It may be necessary to revisit some of these simulations using CMAQ with a 2005 base, with the goal of bridging a smaller gap between 2005 ozone values and 2009 future year ozone values. In this way, less of the projection would be left up to CMAQ, and more would be represented by measured changes in air quality.

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Acronyms

CB4	Carbon Bond IV chemical mechanism
CMAQ	Community Multiscale Air Quality model
EPA	United States Environmental Protection Agency
EGU	Electrical Generating Unit
IPM	Integrated Planning Model
MANE-VU	Mid-Atlantic NorthEast Visibility Union
Midwest RPO	Midwest Regional Planning Organization
MM5	Mesoscale Model 5, the Penn State/NCAR mesoscale meteorological model
NCAR	National Center for Atmospheric Research
NO_x	Reactive oxides of nitrogen, the sum of only NO and NO_2.
OTB	All regulations on the books
OTW	All regulations on the way
ppbv	Parts of ozone (or any other substance) per billion parts of air, by volume
SAPRC99	Statewide Air Pollution Research Center (1999) chemical mechanism
SIP	State Implemetation Plan
SMOKE	Sparse Matrix Operator Kernel Emissions
VISTAS	Visibility Improvement State and Tribal Association of the Southeast
VMT	Vehicle Miles Traveled
WRF-CHEM	Weather Research and Forecasting model, with chemistry.